DEVELOPMENT OF LIQUID SPRAY TRIGGERING AND CONTROL

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A thesis submitted in fulfillment of the
requirements for the award of the degree of
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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project and in myopinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This project presents the study about development of liquid spray triggering and control in a direct injection gasoline injector of a gasoline engine. The objectives of the study is to develop control system using a parameters of time and pressure in order to identify the spray characteristics including spray angle, spray tip penetration and spray width. The scopes of this research are choosing control system due to type of injection, setup test rig for experimental using high pressure chamber and develop control and triggering system in order to control the timing and delay of the injector. After test rig fabrication is done and all equipment has been setup, experiment is done by supplying pressure at 4 Bar from high pressure pump to fuel injector that attach to high pressure chamber. Ambient temperature was set to 300 K and ambient pressure is 0.1 Mpa. Simple triggering and control has been developing using MATLAB Simulink and the result was analyzed due to sample of calculation.

ABSTRAK

Projek ini menunjukkan kajian tentang membangunkan sistem kawalan semburan cecair dalam injektor petrol bagi enjin gasoline. Tujuan kajian ini adalah untuk membangunkan sistem kawalan dengan menggunakan parameter masa dan tekanan untuk mengenal pasti ciri-ciri semburan termasuk sudut semburan, penetrasi semburan dan lebar semburan. Ruang lingkup dalam penelitian ini adalah memilih sistem kawalan mengikut jenis injektor, menyediakan rangka ujian bagi melakukan eksperimen dengan menggunakan kebuk bertekanan tinggi dan membina sistem kawalan untuk mengawal masa dan kelewatan Injektor. Setelah fabrikasi rangka ujian dilakukan dan semua peralatan telah disediakan, eksperiman dilakukan dengan membekalkan tekanan sebanyak 4 bar dari pam bertekanan tinggi ke injektor yang terletak di kebuk tekanan tinggi. Suhu persekitaran ditetapkan untuk 300K dan tekanan diberi sebanyak 0,1Mpa. Sistem kawalan injektor dibina menggunakan aturcara MATLAB Simulink dan analisis keputusan dibandingkan dengan penyelidikan terdahulu dan contoh pengiraan.

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LIST OF ABBREVIATIONS

GDI	Gasoline Direct Injection
ECU	Electronic Control Unit
EFI	Electronic Fuel Injection
Fps	Frames Per Second

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Fuel injection control system directly affects the fuel efficiency and pollution level of automotive engines. Since 1970s, the environment pollution and energy consumption have become serious concerns associated with engine control technology. The self-tuning control technique is applied to improve the engine performance by controlling the engine speed and exhaust flow. Most fuel injection systems are for gasoline or diesel applications. With the advent of electronic fuel injection (EFI), the diesel and gasoline hardware has become similar. EFI's programmable firmware has permitted common hardware to be used with different fuels.

The fuel injection system, on the other hand, is actually quite simple. Fuel is forced under pressure, through a fuel supply line to the injectors. The control unit tells each injector when to open, and the fuel is then released into the cylinder. The fuel injector is made to atomize the fuel as it passes through, and the fuel that's under pressure helps the atomization. Each cylinder virtually receives the same amount of fuel, which means the fuel is burned more completely thus increasing fuel economy.

In addition to the fuel economy of the injectors, the computer control system also consists of several sensors that are strategically placed on the engine, that help the computer determine how much fuel to release into the cylinders.

1.2 PROBLEM STATEMENT

In most spray applications, spray characteristics, such as droplet size and distribution, are highly dependent on the specific spray nozzle used,control in the system which makes it difficult to alter them without a complete overhaul of the system. The implementation of spray control that could enable manipulation of spray behavior and parameters, as necessary, would enhance the versatility and efficiency of sprays.

1.3 PROJECT BACKGROUND

The aim of this project is to study about triggering and control system spray in a direct injection gasoline injector of a gasoline engine. Parameters like pressure and time will use to conduct the experiment.

1.4 OBJECTIVE

The objectives of the study are:

a) To study about fuel injection system.
b) To develop a triggering and control system based on time and pressure difference.

1.5 SCOPE OF WORK

There are three scopes in this study:

a) Study on fuel injection triggering and control system.
b) Setup test rig for experimental using 76mm high pressure chamber.
c) Develop simple triggering and control using MATLAB Simulink

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to fuel injection triggering and control system. A review of other relevant research studies is also provided. Substantial literature has been studied on injection timing and pressure. The review is organized chronologically to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. The review is detailed so that the present research effort can be properly tailored to add to the present body of literature as well as to justly the scope and direction of the present research effort. The research concludes about fuel injection system, control mechanism and spray behaviors.

2.2 FUEL INJECTION SYSTEM

A fuel injection system is designed and calibrated specifically for the types of fuel it will handle. Most fuel injection systems are for gasoline or diesel applications. With the advent of electronic fuel injection (EFI), the diesel and gasoline hardware has become similar. EFI's programmable firmware has permitted common hardware to be used with different fuels. Carburetors were the predominant method used to meter fuel on gasoline engines before the widespread use of fuel injection. A variety of injection systems have existed since the earliest usage of the internal combustion engine.

The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on low pressure created by intake air rushing through it to add the fuel to the airstream.

Basic components in fuel injection system are fuel injector, high speed camera and electronic control unit (ECU) such as injector driver and digital delay generator for the signal line while other components such as fuel tank, fuel filter, high pressure pump and pressure regulator for the fuel line. In the laboratory experiment, high pressure chamber is used as a main character in order to identify spray patterns. Some of the experiment that using high speed camera can trigger with personal computer and ECU. The data gained will show in the personal computer automatically.

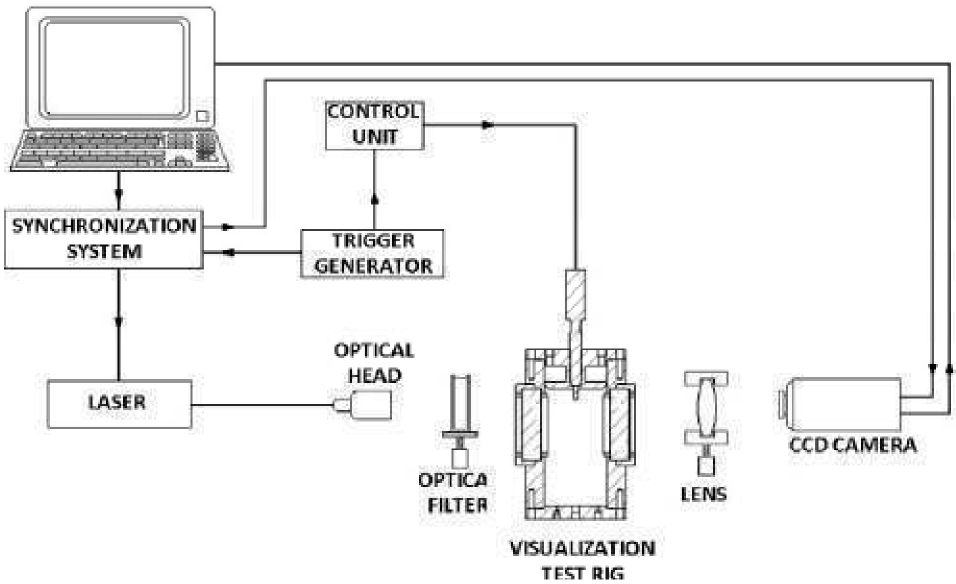

Figure 2.1: Fuel injection system

Source: J.M Desantes, 2009

2.2.1 Fuel Injector

Fuel injectors are nozzles that inject a spray of fuel into the intake air. They are normally controlled electronically, but mechanically controlled injectors, which are cam operated, also exist. A metered amount of fuel is trapped in the nozzle end of the injector, and a high pressure is applied to it, usually by a mechanical compression process of some kind. At the proper time, the nozzle is opened and fuel is sprayed into the surrounding air. The amount of fuel injected each cycle is controlled by injector pressure and time duration of injection.

An electronic fuel injector consists of the following basic components which is valve housing, magnetic plunger, solenoid coil, helical spring, fuel manifold and pintle (needle valve). When not activated, the coil spring holds the plunger against its seat, which blocks the inlet flow of fuel. When activated, the electric solenoid coil is excited, which moves the plunger and connected pintle (needle valve). This opens the needle valve and allows fluid from the manifold to be injected out the valve orifice. The valve can either be pushed opened by added pressure from the plunger or it can be opened by being connected to the plunger, which then releases the pressurized fuel. Each valve can have one or several orifice openings. In mechanically controlled injectors there is no solenoid coil and the plunger is moved by the action of a camshaft.

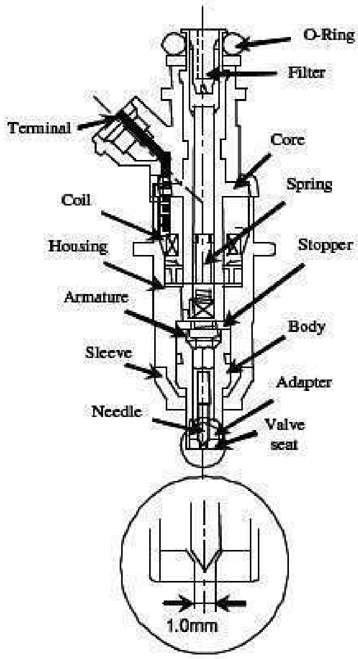

Figure 2.2 : Fuel Injector

Source: Lee, C.S 2009

2.2.2 High speed camera

In order to get different spray characteristic in term of different timing and pressure controlled by ECU, it is require a high speed camera. An example of high speed camera that mostly use is Photron, Fastcam-APX-RS. This camera provides full megapixel resolution images at frame rates up to 3,000 frames per second (fps), 512 x 512 pixels resolution at 10,000 fps and at reduced frame rates to an unrivaled frame rate of 250,000 fps.

Utilizing Photron's advanced CMOS sensor technology, the APX-RS provides the higher light sensitivity than any other comparable high-speed imaging system. Both color and monochrome models are available, both with excellent anti-blooming capabilities. A user selectable 'Region of Interest' function enables the active image area to be defined in steps of 128 pixels wide by 16 pixels high to allow the most efficient use of frame rate, image resolution and memory capacity for any event. Up to 20 commonly used configurations can be saved to memory for future operation. Available with Gigabit Ethernet, Fire wire and fiber optic communications, this compact camera can provide exposure durations as short as 2 microseconds and is easily operated in the field with or without a computer through use of the supplied remote keypad, enabling full camera setup, operation and image replay.

Figure 2.3: High speed camera

Source: Photron 2010

2.2.3 Injector driver

Injector driver modules work with the central computer system and the fuel injection system in a vehicle. Only vehicles with fuel-injection systems will use an injector driver module. Engines that need high pressure fuel injection rely on injector driver to control the fuel injection system. The main purpose of an injector driver is to control the amount and timing of fuel injection within the vehicle's system.

Fig 2.4 : Injector Driver

Source: www.thunderracing.com

2.2.4 Digital delay generator

Digital delay generator is a piece of electronic test equipment that provides precise delays for triggering, syncing, delaying and gating events. It is used in many types of experiments, controls and processes where electronic timing of a single event or multiple events to a common timing reference is needed. Similar to a pulse generator in function but with a digital delay generator the timing resolution is much finer and the delay and width jitter much less.

Figure 2.5: Digital delay generator

Source: www.highlandtechnology.com

2.3 SPRAY CHARACTERISTICS

The microscopic spray characteristic including axial spray tip penetration, spray width and spray angle are shown in figure 2.6. The spray tip penetration and spray width were defined as maximum distance from the nozzle tip of the side view spray image and maximum radial distance from the bottom view, respectively. Also the spray cone angle is defined as the interval which is formed by the nozzle tip and two straight lines wrapped with the maximum outer side of the spray. Amirruddin, A.K. (2009) says that the higher ethanol contains the spray spread faster, present longer penetration distance.

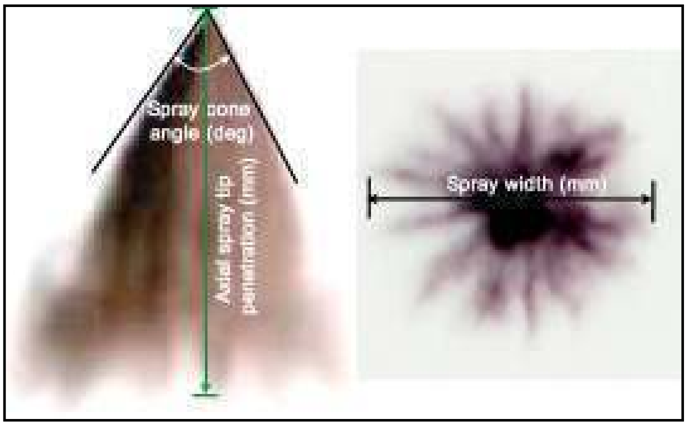

Figure 2.6: Definition of spray characteristic (sprays tip penetration, spray width and spray angle)

Source: Lee, C.S et al. 2009

An evaluation of the correlations between spray tip and function of time, indicated that the formula developed by Dent, best predict the equation :

$$S = 3.07\ (P/\ p)^{1/4}\ (tdn)^{1/2}\ (294/T)^{1/4} \tag{2.1}$$

Where P, pressure across the nozzle, *p*, density of fuel, t, time after start of the injection, d, diameter of nozzle and T, ambient temperature.

2.4 CIRCUIT 555 TIMER IC

The **555 Timer IC** is an integrated circuit (chip) implementing a variety of timer and multivibrator applications. The IC was designed by Hans R. Camenzind in 1970 and brought to market in 1971 by Signetics (later acquired by Philips). The original name was the SE555 (metal can)/**NE555** (plastic DIP) and the part was described as "The IC Time Machine". It has been claimed that the 555 gets its name from the three 5 kΩ resistors used in typical early implementations, but Hans Camenzind has stated that the number was arbitrary.

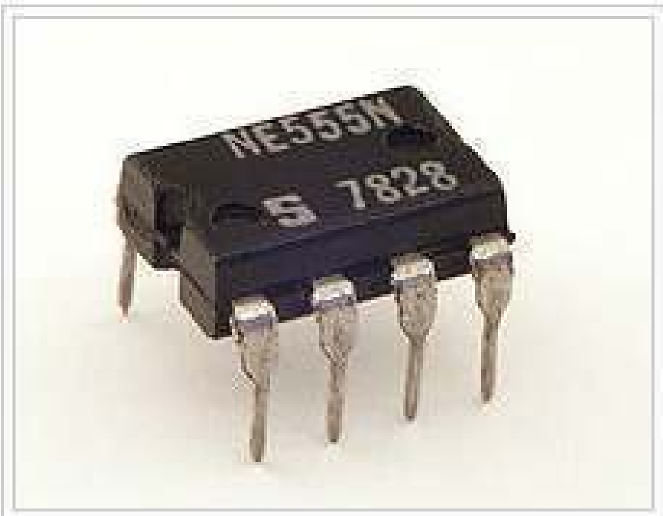

Figure 2.7: NE 555 IC

Source: Lubkin, Gloria B., Power Applications of High-Temperature Superconductors, Physics Today 49, March 1996.